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STATIC AND DYNAMIC FRACTURE PROPERTIES FOR ALUMINUM ALLOY 7475-T651 AND T7351

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AIR FORCE MATERIALS LABORATORY
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio

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This technical report has been reviewed and is approved for publication.

David C Watson

DAVID C. WATSON
Project Monitor

FOR THE COMMANDER

Albert Olevitch

ALBERT OLEVITCH
Chief, Materials Engineering Branch
Materials Support Division

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A broad base of mechanical property data were developed on two plates of Al 7475. One of the 1-1/2-inch thick plates was in the T7351 condition and one was in the T651 condition. The tensile properties of the T651 plate were higher than those of the T7351 plate. Nearly all of the fracture toughness tests were invalid by ASTM test standards; those that were valid indicate the material possesses good toughness. The conditional toughness values (K_Q) for identical test conditions indicate the T7351 processing

possesses the superior toughness property.

The smooth and notched fatigue properties were about equal to those of other 7000-series aluminum alloys. Constant amplitude fatigue crack growth resistance was better than some older 7000-series alloys and similar to other new 7000-series alloys while the stress corrosion cracking properties in a salt water environment were excellent.

Most of the tests were repeated using specimens that had been subjected to 250°F (121°C) for 1000 hours. This time-temperature exposure resulted in: (1) a slight reduction in tensile strength, (2) a slight increase in conditional toughness (K_Q) for the T651 plate and a small decrease in K_Q for the T7351 heat treated plate, (3) a slight reduction in fatigue properties, and (4) negligible effect on the fatigue crack growth rate and corrosion properties.

FOREWORD

This final report was submitted by the University of Dayton Research Institute, Dayton, Ohio, under contract F33615-74-C-5024, Project No. 7381, "Materials Application", Task No. 738106, "Engineering and Design Data", Job Order 73810678, with the Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. David Watson, AFML/MXE, was the Laboratory Project Monitor.

The effort was over the period of October 1973 through December 1974. The author, Mr. Russell R. Cervay, is responsible for the program direction. The author would like to extend recognition to Messrs. Eblin, Marton, and Woleslagle of the University of Dayton Research Institute for performing the testing involved in this reported program, and to Mr. C. Houston of the Air Force Materials Laboratory for performing the chemical analysis.

This report was submitted by the author in April 1975.

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SECTION I
INTRODUCTION

The test material was orginally presented by its producer, ALCOA, as aluminum X7475 with a 467 processing. Subsequently the 467 processing was further refined into three heat treatments, T651, T7651, and T7351. The producer claims the T651 heat treatment is superior in strength, whereas the T7351 is superior in toughness and corrosion cracking resistance. Process T7651 was developed as a hybrid of the two heat treatments described above and was introduced as possessing strength and toughness capabilities flanked by the two extremes found in the T651 and T7351 processes. Herein are reported mechanical property test results on 1.5 inch thick rolled plates with T651 and T7351 processing. Due to difficulties in procuring the alloy 7475 in the T7651 heat treatment that alloy/temper is still in test and is left to be reported at a later date.

This program developed engineering mechanical property data for a new aluminum alloy, 7475, in two heat treatments, T651 and T7351. Alloy 7475 is a refinement of aluminum 7075 which has relatively poor fracture toughness and stress corrosion properties in the T6 condition. The T7351 condition of the 7075 has improved toughness and stress corrosion properties but these are obtained at a sacrifice to the tensile properties. The test alloy/heat treatments are represented by the producer, ALCOA, as being superior in strength, toughness, and fatigue strength (Ref. 1) compared to currently in-service 7000-series aluminum alloys/heat treatments. Prior testing performed in the Air Force Materials Laboratory on this alloy confirmed its high strength, good cyclic crack growth resistance, improved fatigue strength, and excellent exfoliation resistance. This program is a follow-on to the previous engineering design data program on alloy 7475-T761 and T61, 0.090 inch thick sheet stock, reported in AFML-TR-72-173 (Ref. 2). The encouraging findings associated with the referenced program conducted on the sheet stock prompted this follow-on program on a thicker product form.

SECTION II

MATERIALS, SPECIMENS, AND PROCEDURES

Two plates, 1.50-inch thick, were purchased from the Aluminum Company of America (ALCOA). Overall dimensions of the plates were 36 x 24 inches. The producer provided one plate in each of the heat treated conditions, T651 and T7351. The chemical compositions of the test plates are listed in Table 1. The longitudinal grain direction coincided with the 36-inch dimensions of the plates. Composite photomicrographs of the two plates are shown in Figures 1 and 2.

TABLE 1

CHEMICAL COMPOSITION, WEIGHT PERCENT

Heat Treat.	Zn	Mg	Cu	Cr	Si	Mn	Fe	Ti	Al
T7351	5.5	2.0	1.6	0.18	0.054	0.006	0.07	0.018	Balance
T651	5.6	2.0	1.5	0.19	0.056	0.006	0.07	0.024	Balance

Tensile specimens were machined in accordance with Figure 3. Compact specimens with a thickness of 1.5 inch (Figure 4) were fabricated for the longitudinal and transverse fracture toughness tests. Compact specimens of 3/4-inch thickness were employed for the cyclic crack growth tests, and 1/2-inch thick compact specimens were used for the short transverse oriented stress corrosion cracking tests and fracture toughness tests. Figures 5 and 6 illustrate the notched fatigue test samples with a stress concentration factor equal to 3.0, and smooth fatigue test samples, respectively.

The first digit of all specimen identification numbers, i.e. 6 or 7, discriminates the heat treatment of the plate, T651 or T7351, respectively, from which the specimen was taken. The orientation of the various specimens is designated with the lettering code: (L) longitudinal, (W) transverse, (T) short transverse.

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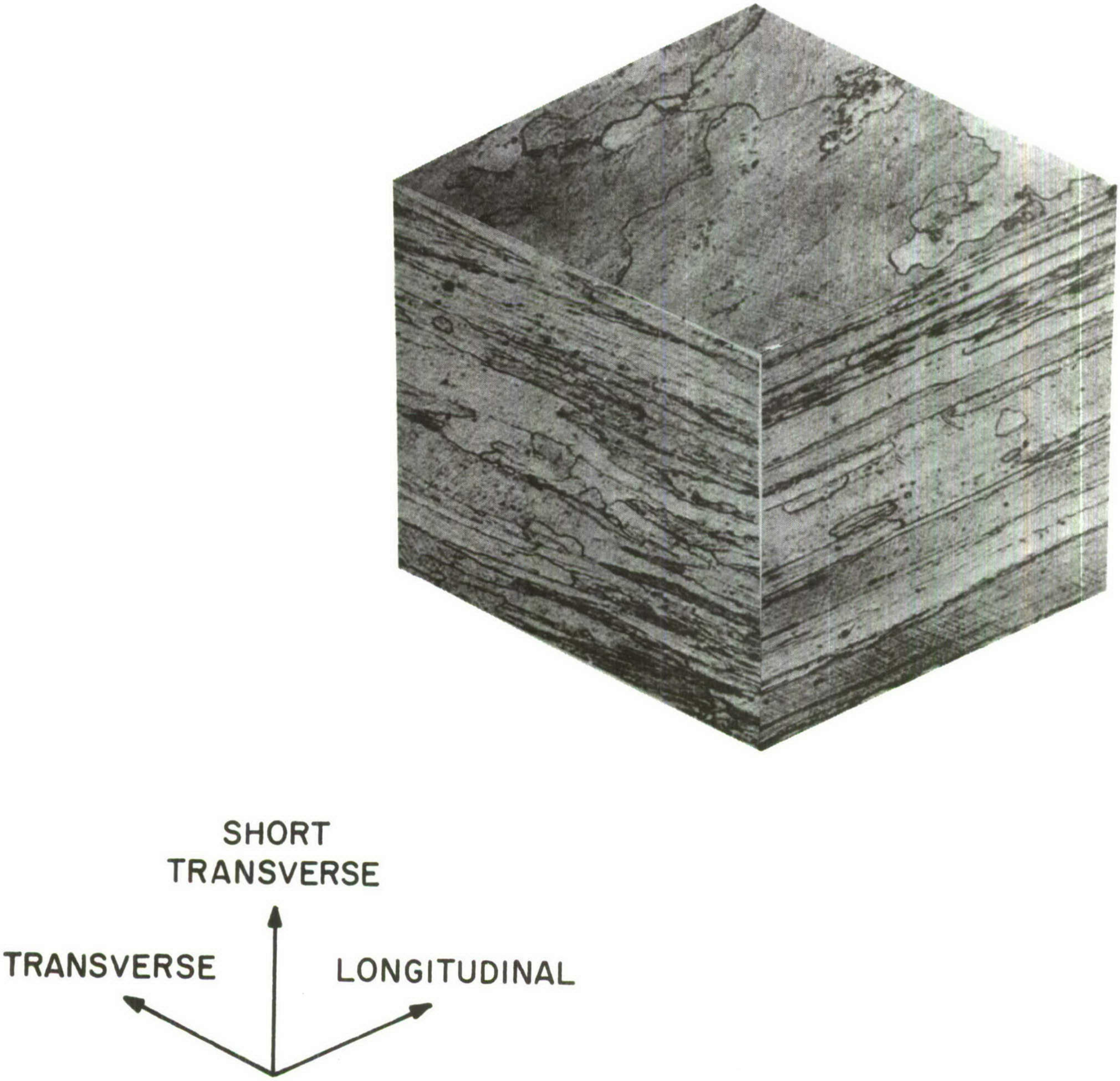


Figure 1. Microstructure of 7475-T651 Aluminum Alloy Rolled Plate (200X).

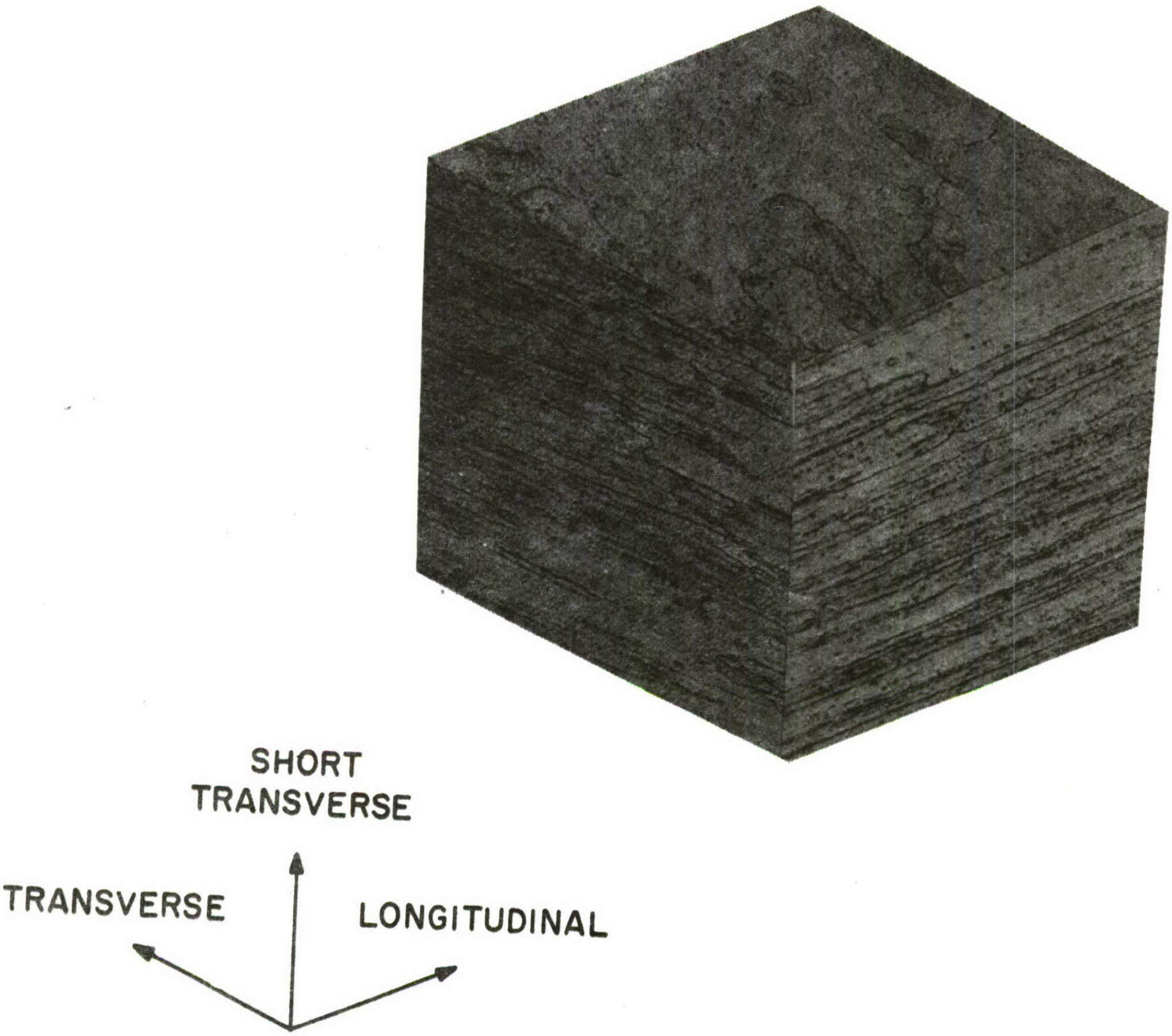


Figure 2. Microstructure of 7475-T7351 Aluminum Alloy Rolled Plate (200X).

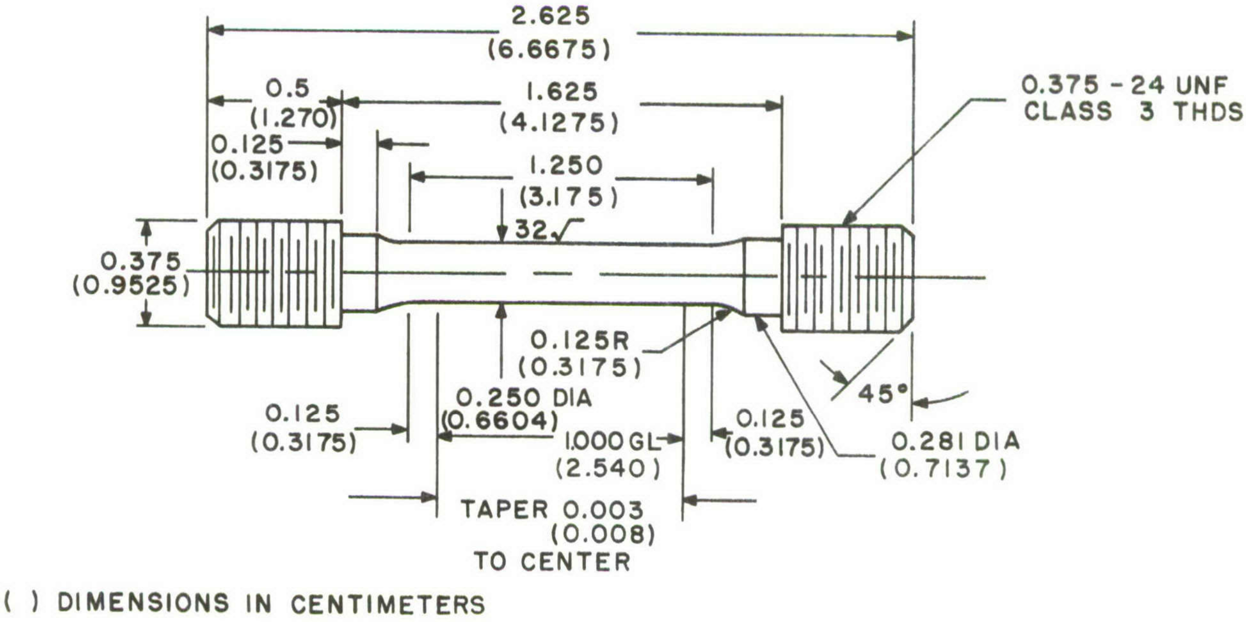
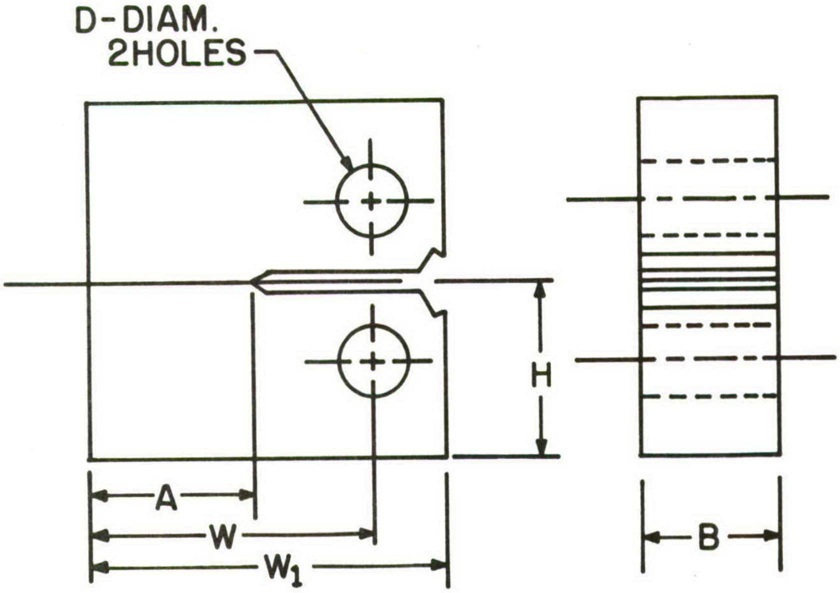


Figure 3. Tensile Specimen Configuration.



DIMENSIONS

SPECIMEN THICKNESS (INCHES)	A	B	W	W_1	H	D
(a) 1 1/2 (3.810)	1.650 (4.191)	1.500 (3.810)	3.000 (7.620)	3.750 (9.525)	1.800 (4.572)	0.625 (1.588)
(b) 3/4 (1.905)	0.835 (2.121)	0.750 (1.905)	1.500 (3.810)	1.875 (4.763)	0.900 (2.286)	0.375 (0.953)
(c) 1/2 (1.270)	0.550 (1.397)	0.500 (1.270)	1.000 (2.540)	1.250 (3.175)	0.600 (1.524)	0.250 (0.635)

( ) DIMENSIONS IN CENTIMETERS

Figure 4. Compact Specimen Configuration.

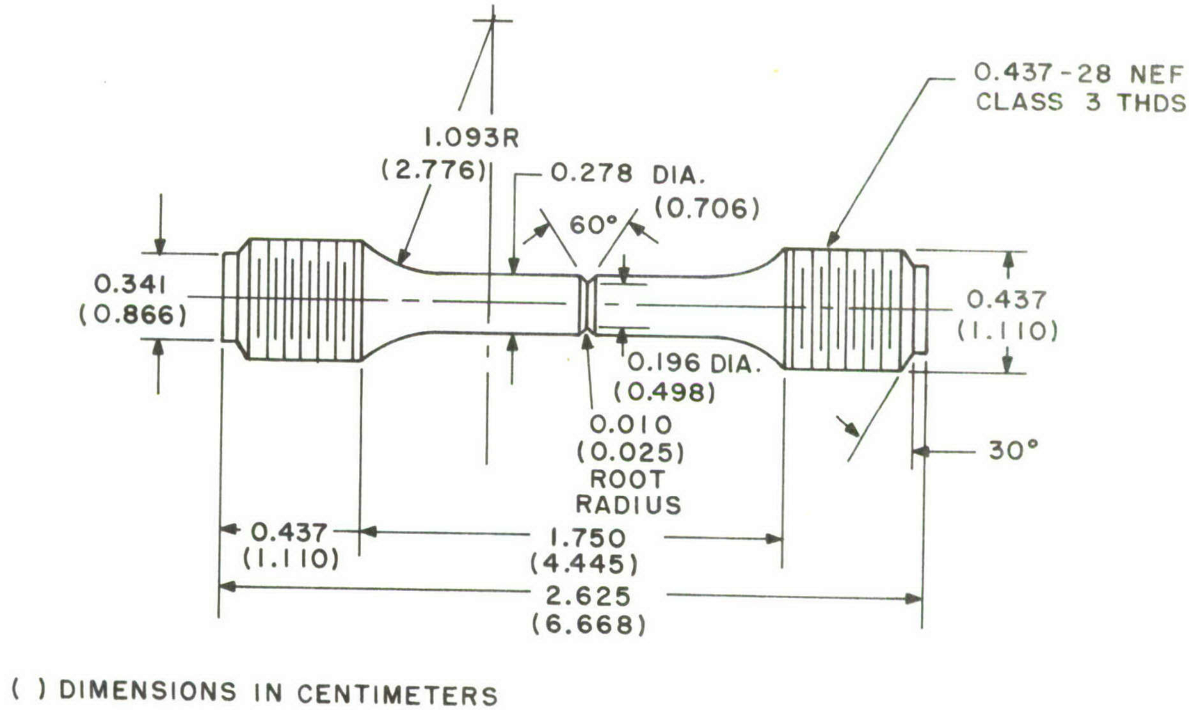


Figure 5. Notched Fatigue Specimen Configuration.

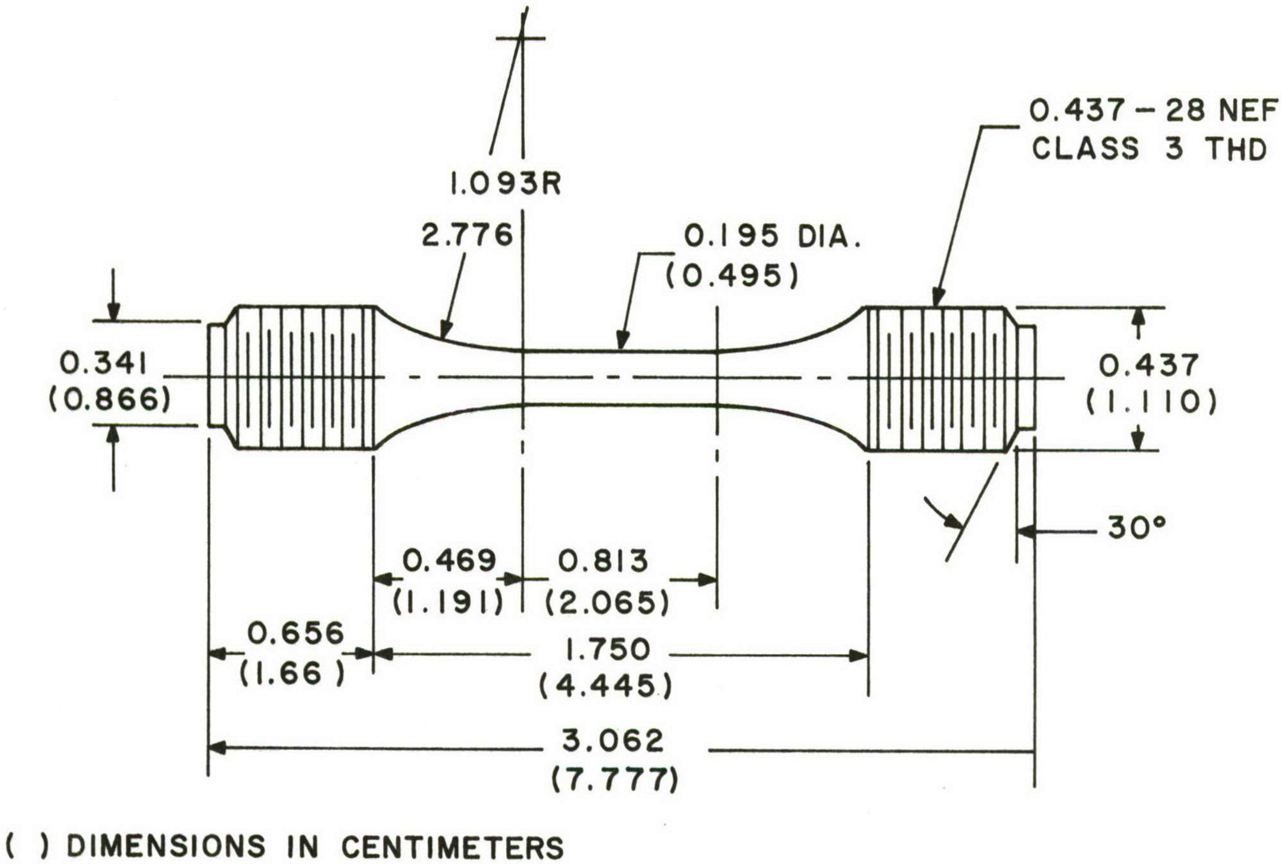


Figure 6. Smooth Fatigue Specimen Configuration.

Tensile tests were conducted at $-65^{\circ}F$ ($-54^{\circ}C$), room temperature, and $200^{\circ}F$ ($94^{\circ}C$) in longitudinal and transverse directions. Fracture toughness tests were performed at $-65^{\circ}F$ ($-54^{\circ}C$), room temperature, and $200^{\circ}F$ ($94^{\circ}C$) in three orientations, longitudinal (L-T), transverse (T-L), and short ransverse (S-L). The room temperature longitudinal tensile and fracture toughness tests were repeated using specimens that underwent a $250^{\circ}F$ ($121^{\circ}C$) 1000-hour time-temperature furnace exposure.

All of the cyclic crack growth test specimens were longitudinally oriented (L-T) and were subjected to test environments of either laboratory air or 3.5 percent salt water solution at room temperature. The room temperature laboratory air crack growth tests were repeated with specimens that underwent the thermal cycle described in the preceding paragraph. Crack growth was visually monitored with a 30x traveling microscope. A computer was employed to perform the cyclic crack growth data reduction.

Longitudinal and transverse-oriented fatigue specimens underwent test in both the smooth ($K_t = 1$) and notched ($K_t = 3$) configuration. Additional smooth, longitudinal fatigue tests were completed at room temperature in laboratory air following a test specimen exposure of $250^{\circ}F$ ($121^{\circ}C$) for 1000 hours.

The threshold for stress corrosion cracking was determined in a 3.5 percent by weight salt water solution. All stress corrosion cracking tests employed short transverse oriented compact specimens. These tests were repeated following the $250^{\circ}F$ ($121^{\circ}C$) 1000-hour time-temperature specimen exposure. Specimens were precracked with constant amplitude cyclic loading at a loading level less than one half of K_{IC}.

When an ASTM standard was available for a test it was followed. In the cases where an ASTM standard is non-existent, e.g. cyclic crack growth testing, the accepted test practices of the material testing community were followed.

SECTION III

RESULTS AND DISCUSSION

The following observations are based on test results from single plates of aluminum alloy 7475 in the T651 and T7351 heat treatments. Conclusions drawn could be altered by more in-depth testing that encompassed lot-to-lot variations.

The test material is a high strength 7000 series aluminum alloy, as indicated in Table 2 and Figure 7. The ultimate and yield strengths are approximately equal to those of the 7475 referenced literature (Ref. 1 and 2). However, over the temperature range of interest the test material is slightly inferior in strength and demonstrated considerably more elongation than did 7075-T76, 7178-T76 or 7175-T736 reported in References 3 and 4. The T651 heat treated plate possesses higher strength (10 to 17 percent) than the T7351 heat treated plate. Figure 7 shows the tensile strength of the two plates as a function of temperature. At a test temperature of 200°F (94°C) the load carrying capability has not yet started to radically taper off, indicating that 200°F(94°C) is probably an acceptable service temperature. For the specimens that were thermal-cycled at 250°F (121°C) for 1000 hours the ultimate strength decreased 6.7 percent for the T7351 heat treated plate and dropped 5.0 percent for the T651 heat treated plate. With the indicated drops in tensile strengths following the exposure, there were similarly small increases in the elongation and reduction of area. The variation in yield strength is essentially the same as that for the ultimate strength observed in Figure 7.

At room temperature, the transverse ultimate strength for the T651 plate is slightly higher than the longitudinal ultimate strength. This was unexpected and is not considered to be significant. Photomicrographs (Figures 1 and 2) were made to verify that the grain structure actually was as labeled by the producer.

(Text Continued on Page 15.)

TABLE 2

TENSILE PROPERTIES OF ALUMINUM ALLOY 7475-T7351
AND T651 PLATE (1.5-INCH THICK)

Specimen	Heat Treatment	Test Temp.	Orientation	Ultimate Strength KSI	Ultimate Strength MPa	Yield Strength KSI	Yield Strength MPa	Elong. In 1 inch G.L. (%)	Reduction of Area (%)
7L4	T7351	R.T.	Longitudinal	72.0	517	59.8	412	15	49
7L5				71.2	490	59.4	409	15	49
7L6				71.5	492	59.3	408	14	45
Avg.				71.6	493	59.5	410	15	48
7T4	T7351	R.T.	Transverse	69.7	480	59.1	407	16	59
7T5				70.1	490	58.8	405	16	39
7T6				70.1	490	58.9	406	18	57
Avg.				70.0	482	58.9	409	17	52
7L1*	T7351	R.T.	Longitudinal	67.2	463	56.0	386	19	59
7L2*				66.3	457	55.9	385	18	56
7L3*				66.9	461	59.0	406	19	-
Avg.				66.8	460	57.0	393	19	58
6L4	T651	R.T.	Longitudinal	79.1	545	71.6	493	17	42
6L5				78.7	542	70.8	488	15	36
6L6				78.2	539	70.4	485	16	34
Avg.				78.7	542	70.9	488	16	37
6T4	T651	R.T.	Transverse	81.8	563	69.0	475	14	27
6T5				82.8	570	69.6	480	15	26
6T6				83.0	572	70.4	485	14	31
Avg.				82.5	568	69.8	481	14	28

*Denotes specimen underwent a thermal cycle of 250°F for 1000 hours before room temperature test.

TABLE 2 (Continued)

TENSILE PROPERTIES OF ALUMINUM ALLOY 7475-T7351
AND T651 PLATE (1.5-INCH THICK)

Specimen	Heat Treatment	Test Temp.	Orientation	Ultimate Strength KSI	Ultimate Strength MPa	Yield Strength KSI	Yield Strength MPa	Elong. In 1 inch G.L. (%)	Reduction of Area (%)
6L1*	T651	R.T.	Longitudinal	73.9	515	64.6	445	17.0	43
6L2*				77.0	530	67.5	465	15.0	33
6L3*				73.7	508	64.3	443	18.0	46
Avg.				74.8	515	65.1	448	17.0	41
7L1	T7351	-65°F -54°C	Longitudinal	76.0	524	63.5	437	12.5	35
7L2				75.8	522	63.2	435	13.2	32
7L3				75.6	521	63.1	435	13.5	36
Avg.				75.8	522	63.2	435	13.5	36
7L7	T7351	200°F 93°C	Longitudinal	60.6	417	-	-	19.5	63
7L8				61.2	421	56.1	386	19.3	58
7L9				61.3	422	56.7	390	22.0	59
Avg.				61.0	420	56.4	388	20.3	60
7T1	T7351	-65°F -54°C	Transverse	74.3	512	62.3	429	17.8	51
7T2				73.9	509	62.1	428	15.8	50
7T3				73.7	508	62.1	428	15.6	49
Avg.				74.0	510	62.2	428	16.4	50
7T7	T7351	200°F 93°C	Transverse	60.5	417	56.8	391	20.0	70
7T8				60.5	417	56.7	390	21.3	65
7T9				59.2	408	55.4	381	20.6	69
Avg.				60.0	413	56.3	388	20.6	68

* Denotes specimen underwent a thermal cycle of 250 °F for 1000 hours before room temperature test.

TABLE 2 (Concluded)

TENSILE PROPERTIES OF ALUMINUM ALLOY 7475-T7351 AND T651 PLATE (1.5-INCH THICK)

Specimen	Heat Treatment	Test Temp.	Orientation	Ultimate Strength KSI	Ultimate Strength MPa	Yield Strength KSI	Yield Strength MPa	Elong. In 1 inch G.L. (%)	Reduction of Area (%)
6L1	T651	$-65^{\circ}F$	Longitudinal	80.6	555	72.0	496	17.2	26
6L2		$-54^{\circ}C$		81.2	560	73.1	504	19.3	24
6L3				81.9	564	74.0	510	18.0	19
Avg.				81.2	560	74.0	510	18.2	23
6L7	T651	$200^{\circ}F$	Longitudinal	70.8	488	66.5	458	24.0	56
6L8		$93^{\circ}C$		70.5	486	68.0	468	20.5	56
6L9				71.9	495	67.6	466	21.4	53
Avg.				71.1	490	68.0	468	22.0	55
6T1	T651	$-65^{\circ}F$	Transverse	86.9	599	74.2	511	12.8	19
6T10		$-54^{\circ}C$		86.8	598	73.9	509	14.3	18
6T3				89.7	618	76.8	529	14.1	15
Avg.				87.8	605	74.9	516	13.7	17
6T7	T651	$200^{\circ}F$	Transverse	76.9	530	68.5	472	21.0	46
6T8		$93^{\circ}C$		74.9	516	66.4	457	19.0	46
6T9				75.4	521	66.3	457	20.4	47
Avg.				75.7	521	67.0	461	20.1	46

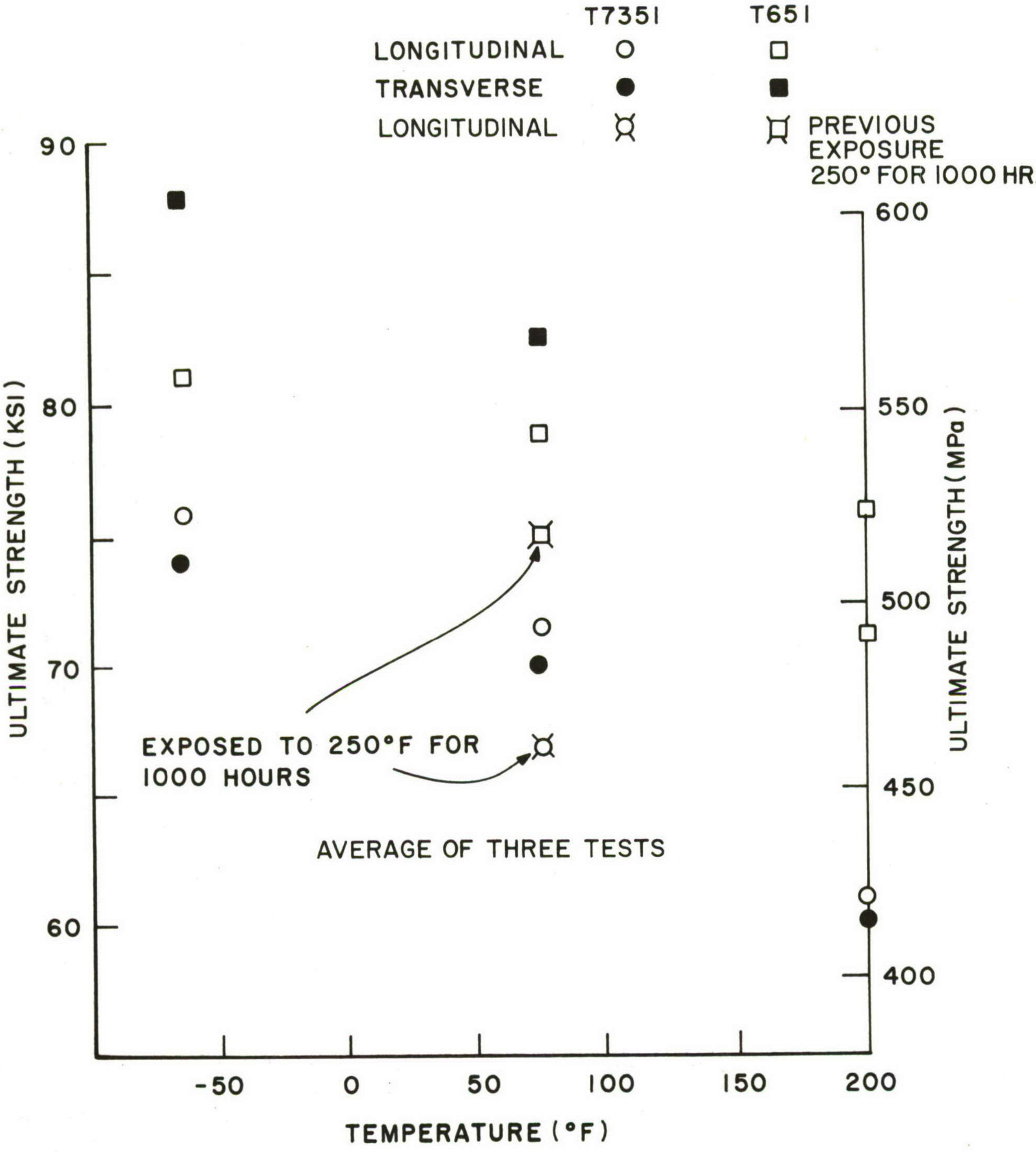


Figure 7. Ultimate Strength of Aluminum 7475-T651 and T7351 versus Temperature.

Figures 8 and 9 present typical stress-versus strain curves for the T651 and T7351 materials, respectively for a room temperature test.

Fracture toughness test results are shown in Table 3. Nearly all of the fracture toughness test results are invalid by ASTM test standard E-399. The invalidity is attributed to gross crack front curvature (tunneling of the crack front) or insufficient specimen thickness. It must be cautioned that all of the observations with respect to the fracture toughness must be considered intuitive impressions since most of the test results are invalid by strict interpretation. Invalidity, in itself, is usually a good indication of the superior toughness of the test material.

The T7351 heat treatment gave higher conditional toughness test results, K_Q, than those found for the T651 plate. Short transverse (S-L) toughness results are appreciably lower than the longitudinal (L-T) or transverse (T-L) specimen test results. The observation is typical when short transverse toughness test results are available. For the T7351 heat treatment the K_Q toughness values decrease slightly with the 250°F (121°C) time-temperature exposure, whereas for the T651 processed plate the K_Q values increased following the time-temperature exposure.

Considerable scatter can be observed in the fatigue test results presented in Figures 10 and 11. The longitudinal and transverse fatigue test results plot in overlapping scatter bands. No distinction can be made as to which heat treatment demonstrated superior fatigue life. The time-temperature exposure reduced the fatigue life of both heat treatments; the fatigue life of the T7351 plate was more extensively diminished than that of the T651 plate (see Figure 10).

In Figure 12 the test alloy's fatigue life is compared to similar fatigue test data from References 1 and 5. The test alloy compares directly with the reference test materials of alloy 7475-T61 and -T761 sheet stock and alloy 7075-T6 sheet.

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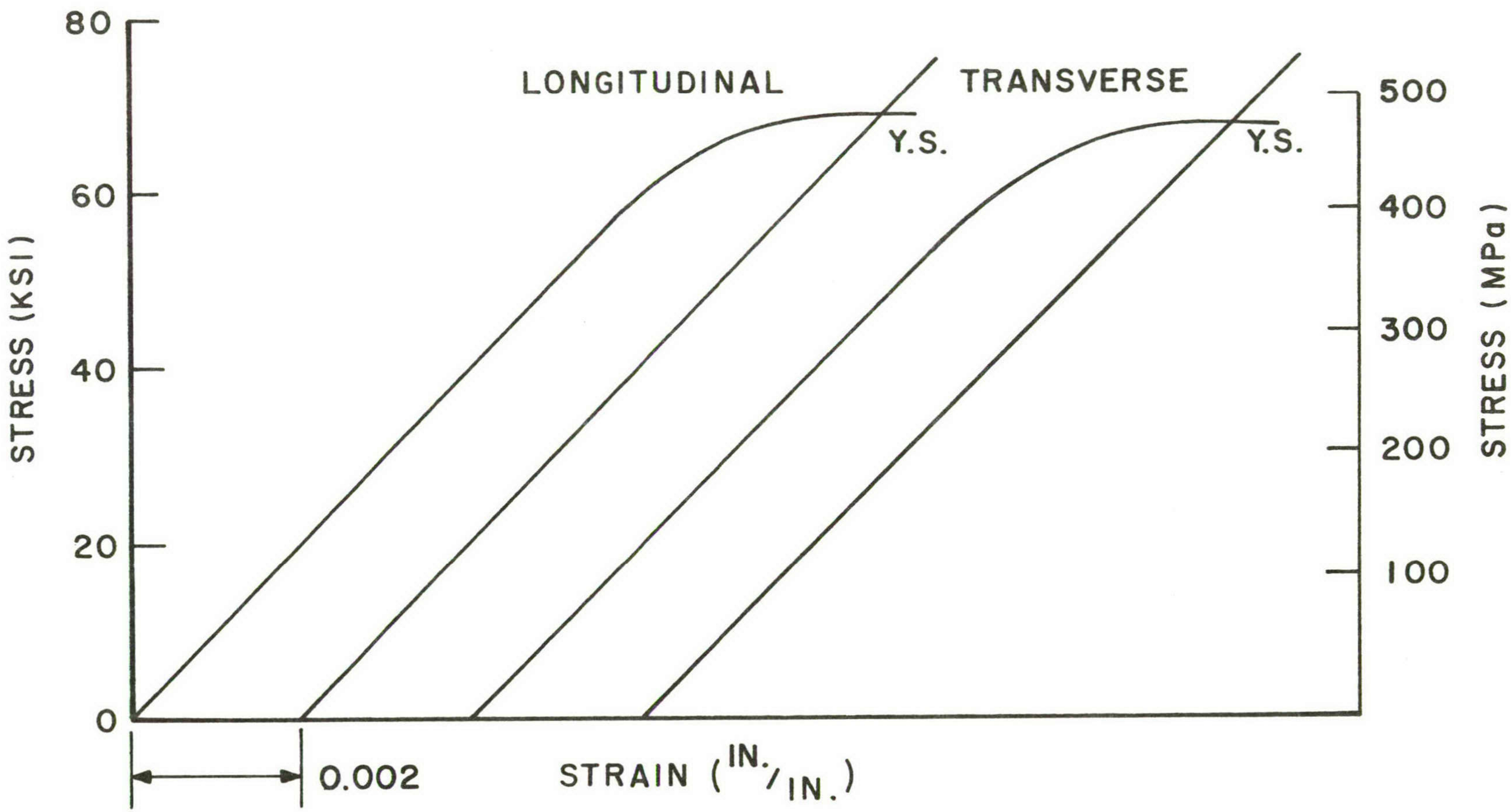

Figure 8. Typical Room Temperature Tensile Stress-Strain Curves for Aluminum Alloy 7475-T651.

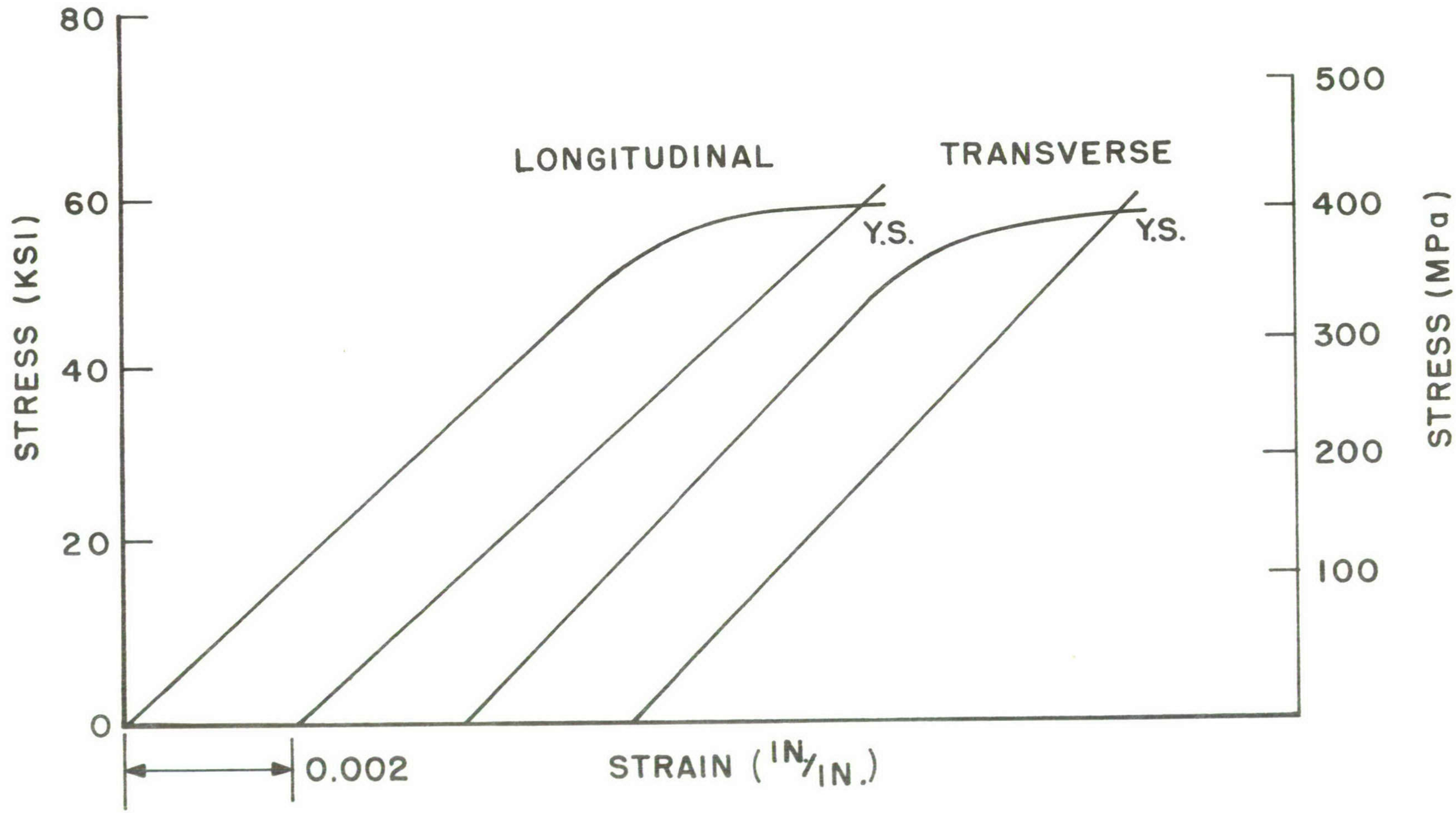

Figure 9. Typical Room Temperature Tensile Stress-Strain Curves for Aluminum Alloy 7475-T7351.

TABLE 3

ALUMINUM 7475-T651 AND T7351 FRACTURE TOUGHNESS TEST RESULTS FOR 1.5-INCH THICK PLATE

Specimen	Heat Treat	Test Temp.	Orientation*	K_Q KSI$\sqrt{\text{IN}}$	K_Q MPa$\sqrt{\text{m}}$	ASTM Valid?
6LW4	T651	70 °F	L-T	50.1	55.0	No
6LW5		21.1 °C		49.0	53.8	No
6LW6				46.7	51.3	No
6WL4			T-L	42.0	46.1	No
6WL5				50.6	55.6	No
6WL6				41.9	46.0	No
6TL4			S-L	37.4	42.5	No
6TL5				34.8	38.2	No
6TL6				36.1	39.7	No
6LW1			L-T	55.9**	61.4	No
6LW2				56.5**	62.1	No
6LW3				52.2**	57.4	No
7LW4	T7351	70 °F	L-T	63.9	70.2	No
7LW5		21.1 °C		66.2	72.4	No
7LW6				60.3	66.3	No
7WL4			T-L	59.7	65.6	No
7WL5				57.4	63.1	No
7WL6				61.0	67.0	No
7TL4			S-L	42.8	47.0	No
7TL5				33.3	36.6	Yes
7TL6				36.8	40.4	Yes
7LW1			L-T	60.2**	66.1	No
7LW2				60.8**	66.8	No
7LW3				57.1**	62.7	No
6LW1	T651	-65 °F	L-T	45.0	49.4	No
6LW2		-53.8 °C		45.5	50.0	No
6LW3				46.6	51.2	No
6WL1			T-L	34.7	38.1	No
6WL2				36.7	40.3	No
7LW1	T7351	-65 °F	L-T	58.2	64.0	No
7LW2		-53.8 °C		63.9	70.2	No
7LW3				60.1	66.0	No
7WL1			T-L	56.9	62.5	No
7WL2				56.7	62.3	No
7WL3				54.7	60.1	No

TABLE 3 (Concluded)

ALUMINUM 7475-T651 AND T7351 FRACTURE TOUGHNESS TEST RESULTS FOR 1.5-INCH THICK PLATE

Specimen	Heat Treat	Test Temp.	Orientation*	K_Q KSI $\sqrt{IN}$	K_Q MPa $\sqrt{m}$	ASTM Valid?
6LW7	T651	200°F	L-T	50.2	55.2	No
6LW8		93.3°C		49.8	54.7	No
6LW9				50.0	54.9	No
6WL7			T-L	49.1	54.0	No
6WL8				48.5	53.3	No
6WL9				49.3	54.2	No
7LW7	T7351	200°F	L-T	70.3	77.2	No
7LW8		93.3°C		65.8	72.3	No
7LW9				71.9	79.0	No
7WL7			T-L	65.3	71.8	No
7WL8				64.1	70.4	No
7WL9				62.9	63.0	No

*L-T Denotes Longitudinal Orientation
T-L Denotes Transverse Orientation
S-L Denotes Short Transverse Orientation
** Exposure to 250°F (121°C) for 1000 hours duration

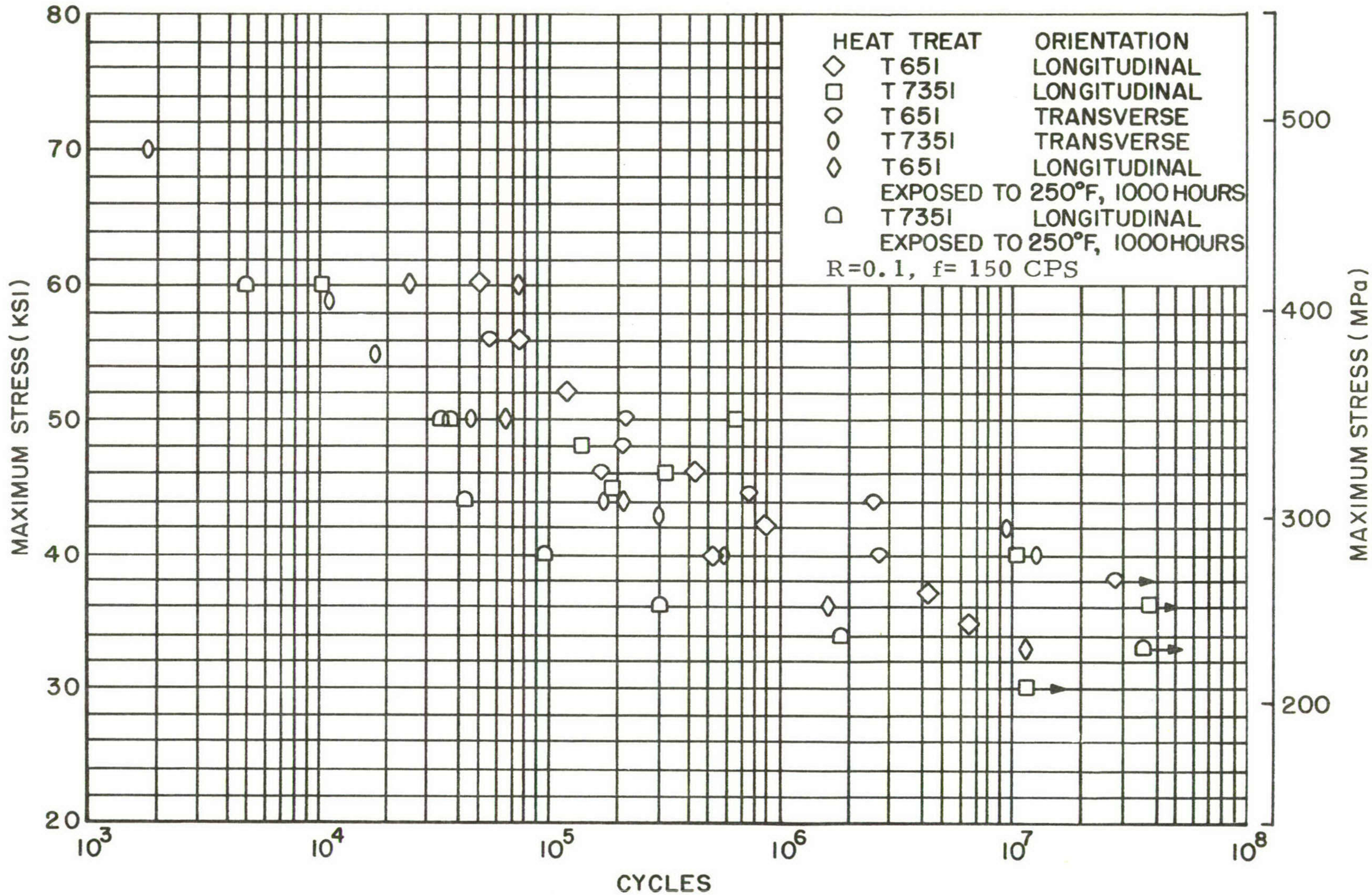

Figure 10. Smooth Fatigue Test Results for Aluminum Alloy 7475-T651 and T7351 at 70°F (21.1°C).

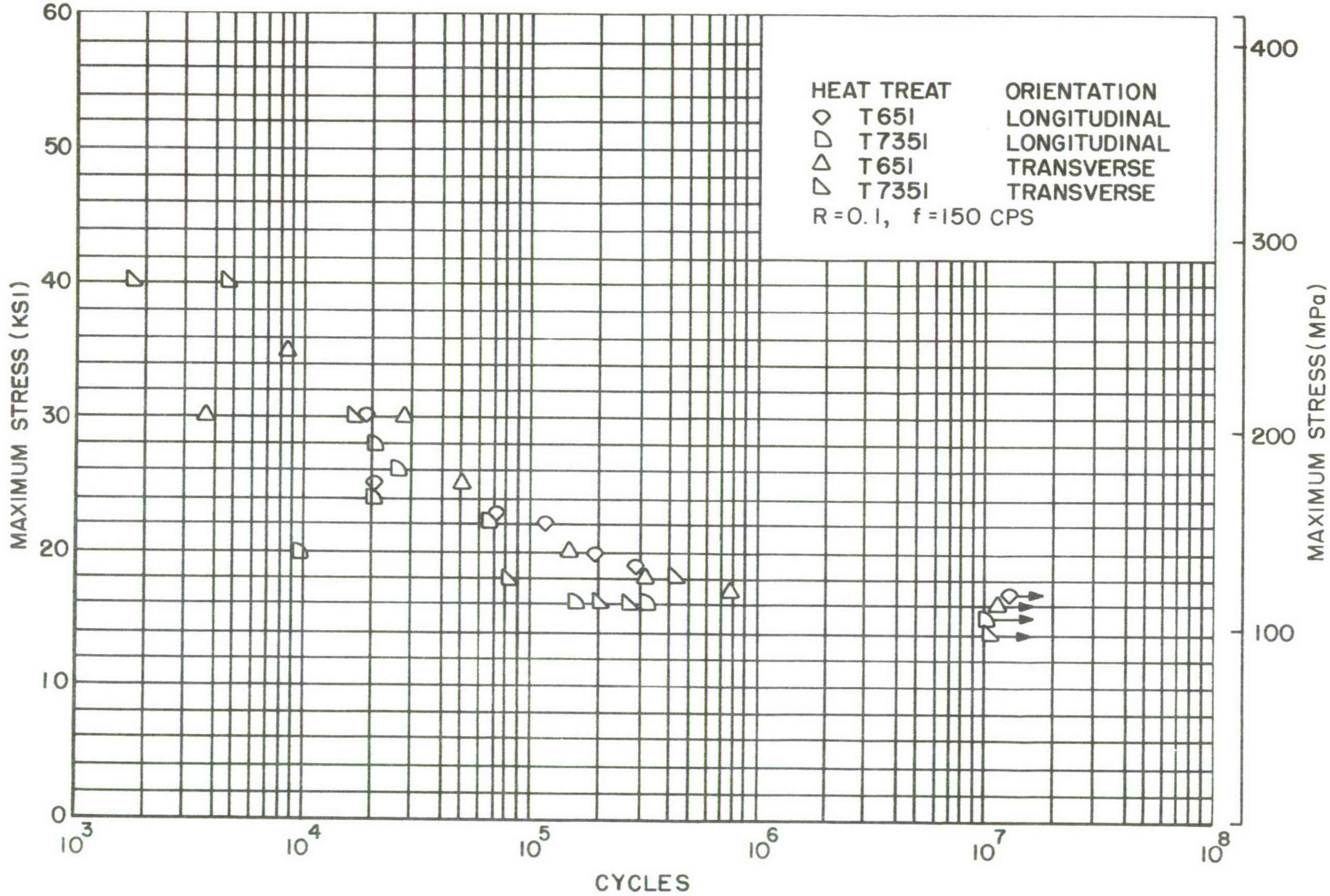

Figure 11. Notched Fatigue Specimen (K_t = 3.0) Test Results for Aluminum Alloy 7475-T651 and T7351, 1.50-inch Plate at 70°F (21.1°C).

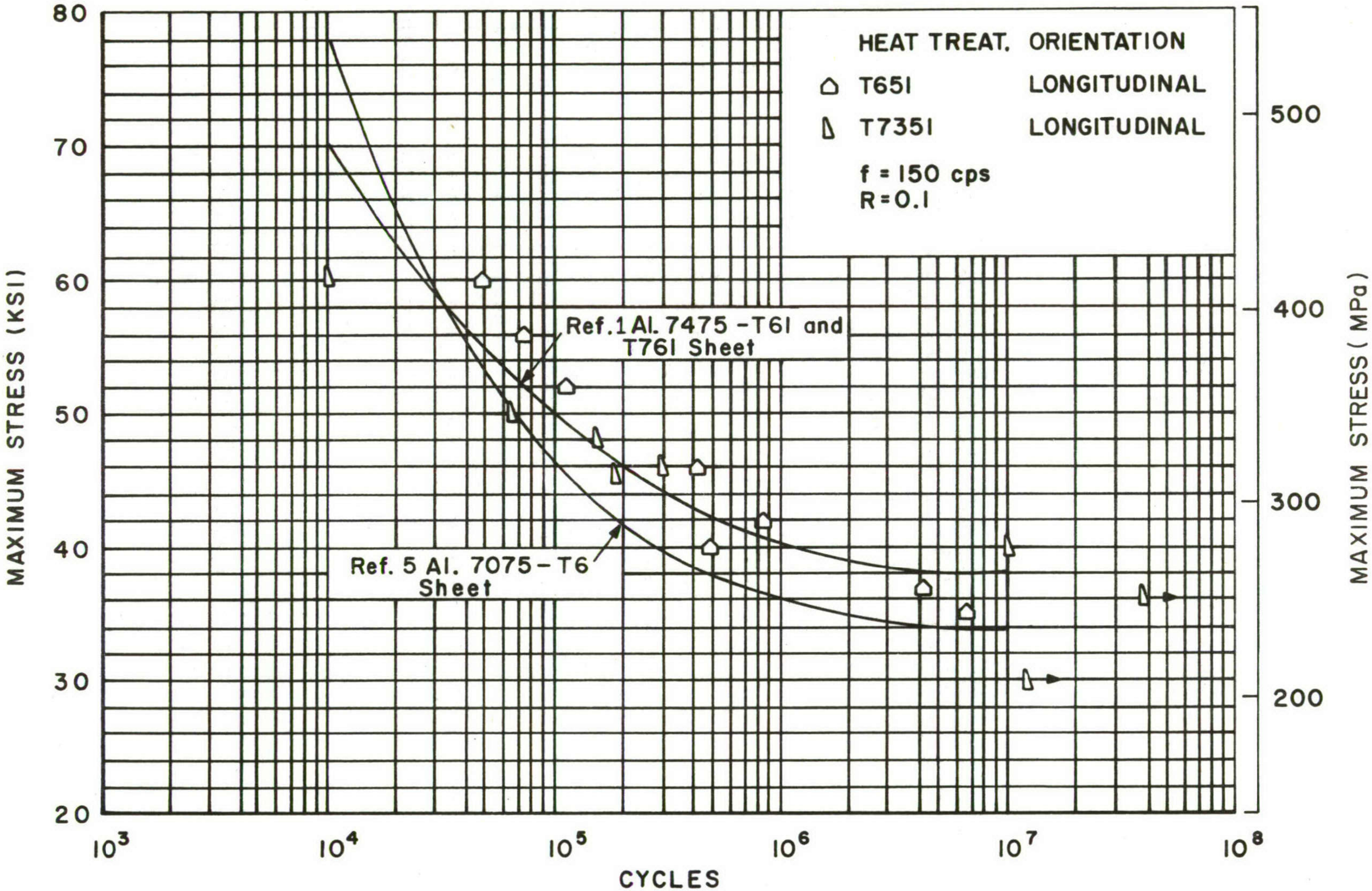

Figure 12. Smooth Fatigue Specimen (K_t = 1.0) Test Results for Aluminum Alloy 7475-T651 and T7351 with Reference Data at 70°F (21.1°C)

The constant amplitude cyclic crack growth test results shown in Figure 13 indicate that the T7351 heat treatment is slightly better in crack growth resistance than the T651. Crack growth rate is approximately doubled by the presence of a 3.5 percent NaCl solution. The cyclic crack growth test results for the material thermal-cycled at 250°F (121°C) for 1000 hours (Figure 14) plots in an overlapping scatter band to that of the unexposed material; crack growth resistance was not affected by the time-temperature exposure. Figure 15 is a replot of the unexposed material laboratory air test results along with the crack growth rate curves for alloy 7475, 0.090-inch sheet stock (Ref. 2), alloy/temper 7175-T736 forging (Ref. 4), and aluminum 7075-T651 plate (Ref. 6). Crack growth resistance of the test plate is identical to that of sheet stock. Alloy/temper 7175-T736 demonstrated better crack growth resistance than the alloy 7475 in either the T7351 or T651 temper; the aluminum 7075 manifests a faster crack growth rate than the test alloy. The test material demonstrated approximately the same cyclic loading crack propagating rate as those for other newly developed 7000-series alloys.

Figure 16 illustrates the pitting that occurred on the surfaces of the stress corrosion samples. Specimens with the two different tempers developed equal amounts of corrosion pitting. Corrosion test results are listed in Table 4. Neither heat treatment showed any susceptibility to stress corrosion cracking in the sodium chloride test solution in either the as-received condition or following the thermal cycle conditioning.
(Text Continued on Page 29.)

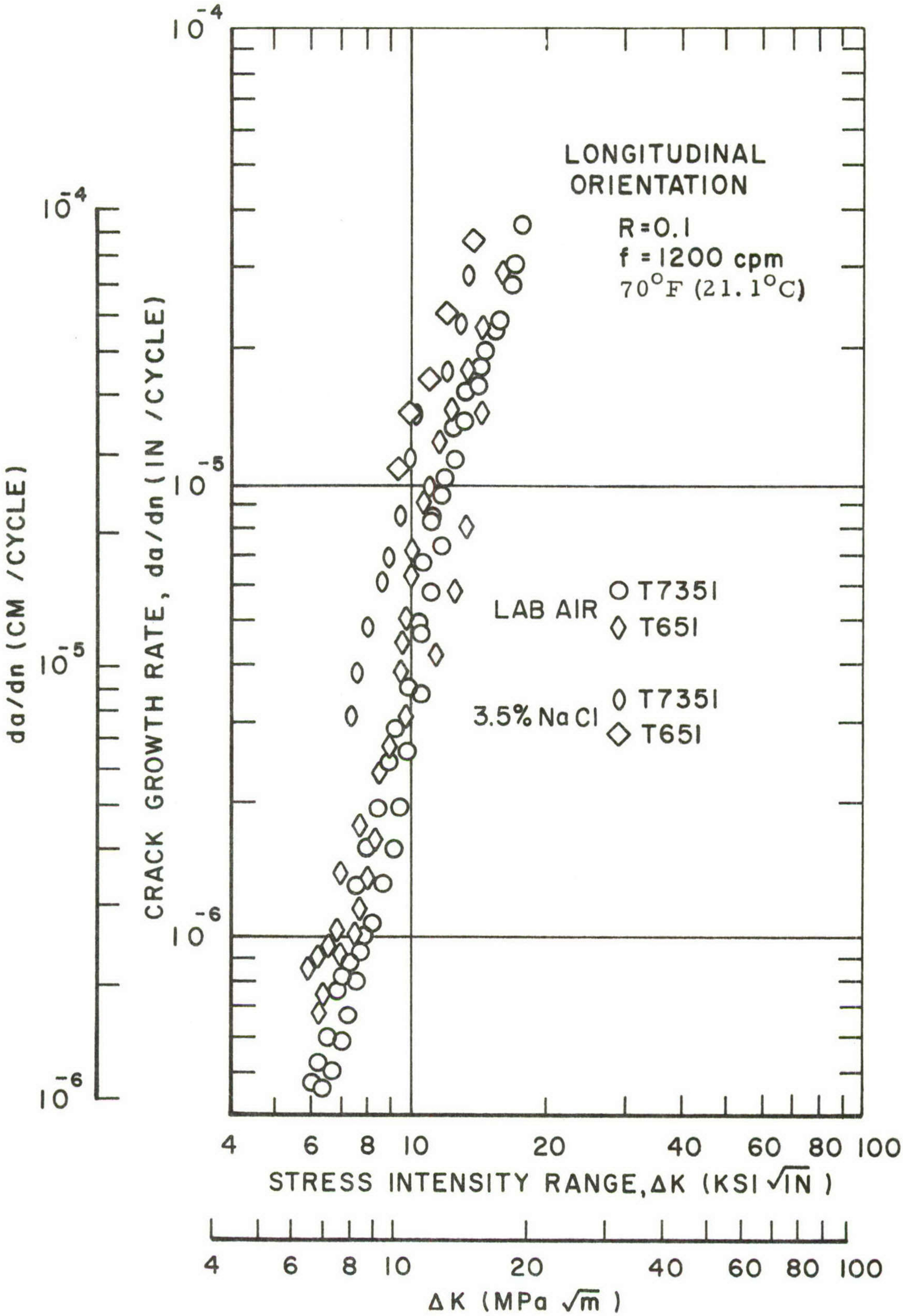

Figure 13. Aluminum Alloy 7475-T651 and T7351 Plate (1.50 in thick) Crack Growth Rate versus Stress Intensity Range.

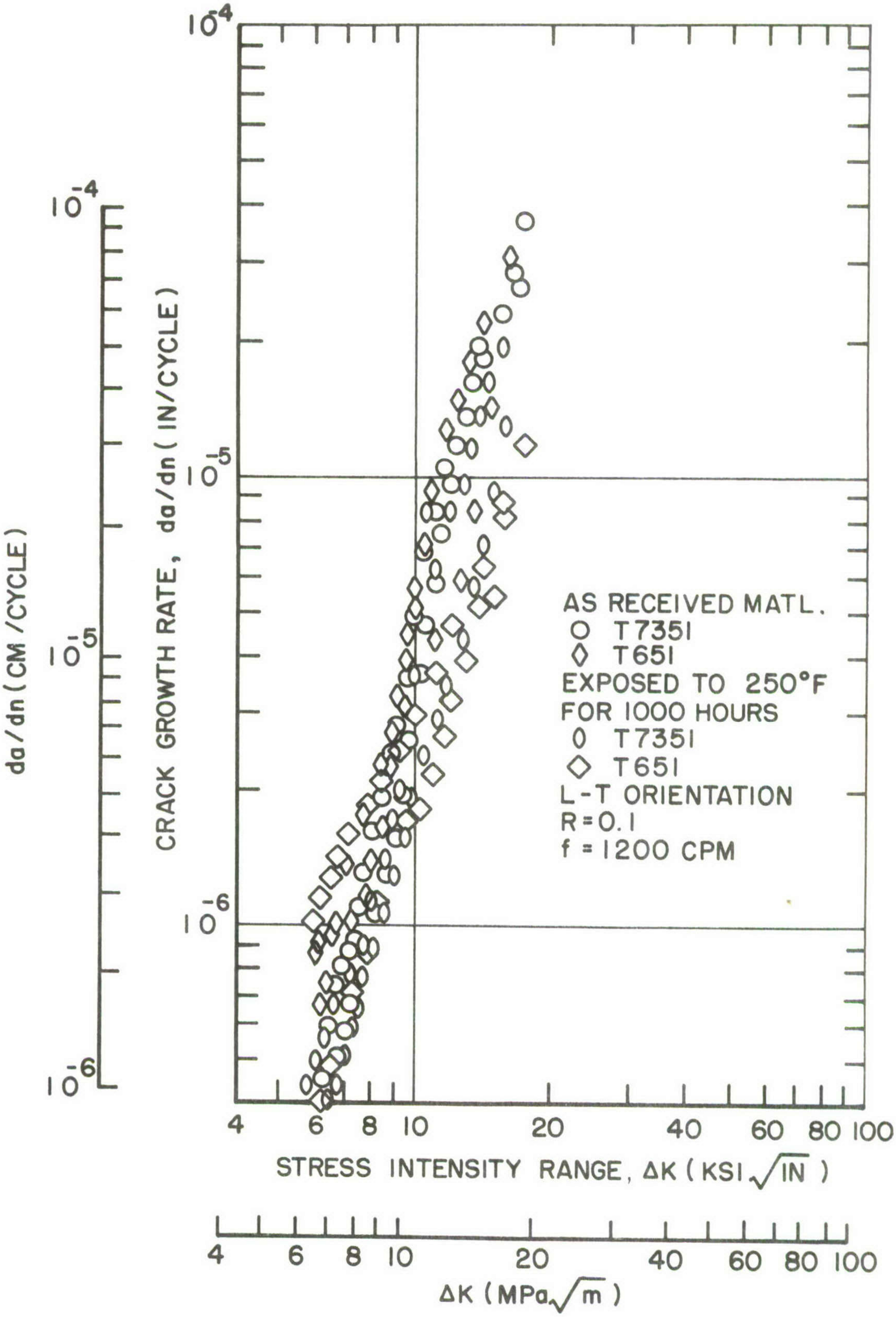

Figure 14. Room Temperature Cyclic Crack Growth Rate Versus Stress Intensity Range for As-Received Aluminum Alloy 7475-T651 and T7351 Plate (1.50-in thick) and Specimens Thermal Cycled at $250^{\circ}F$ ($121^{\circ}C$) for 1000 Hours.

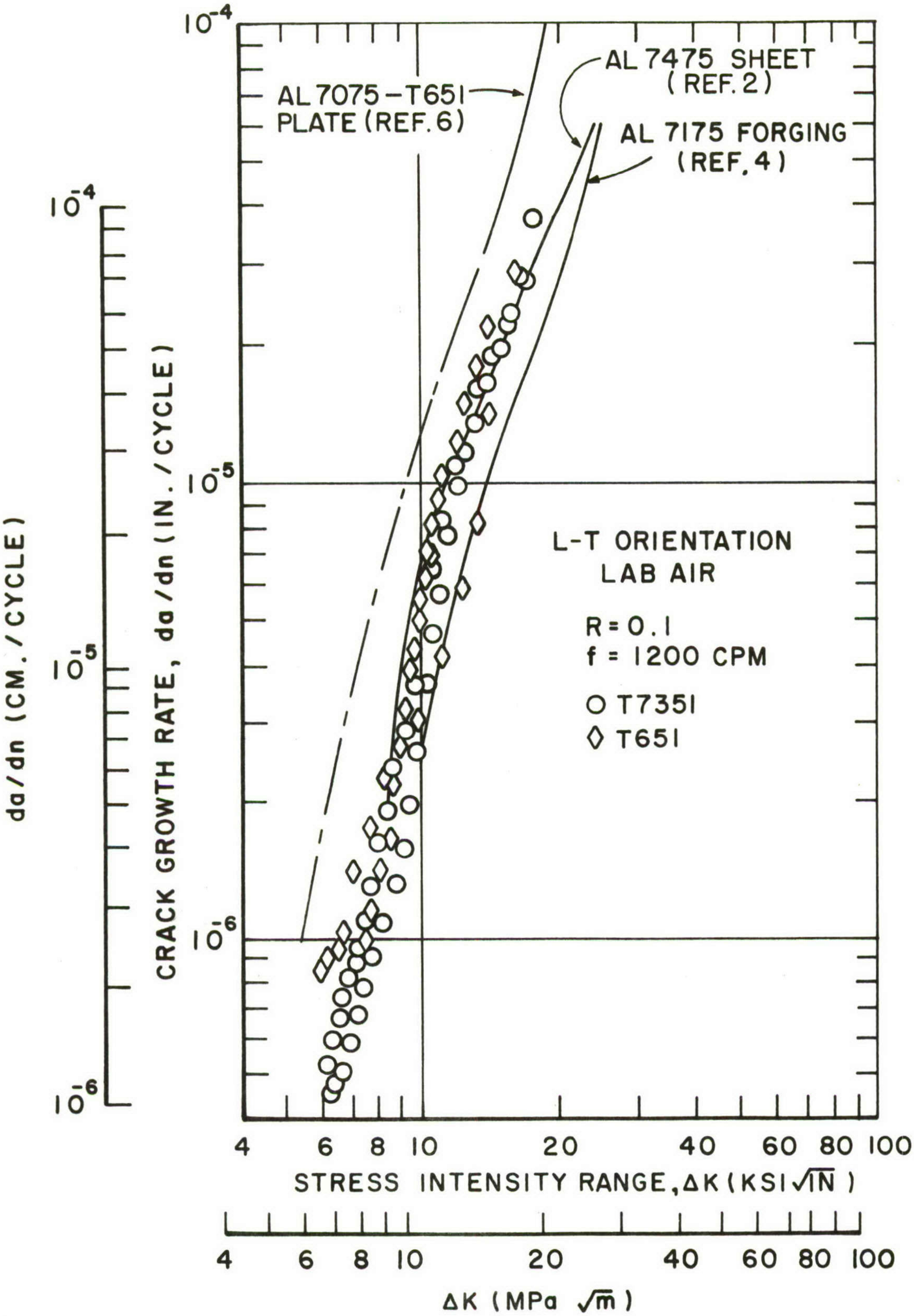

Figure 15. Room Temperature Cyclic Crack Growth Rate Versus Stress Intensity Range for Aluminum Alloy 7475-T651 and T7351 Plate (1.50-in thick) with Reference Test Data.

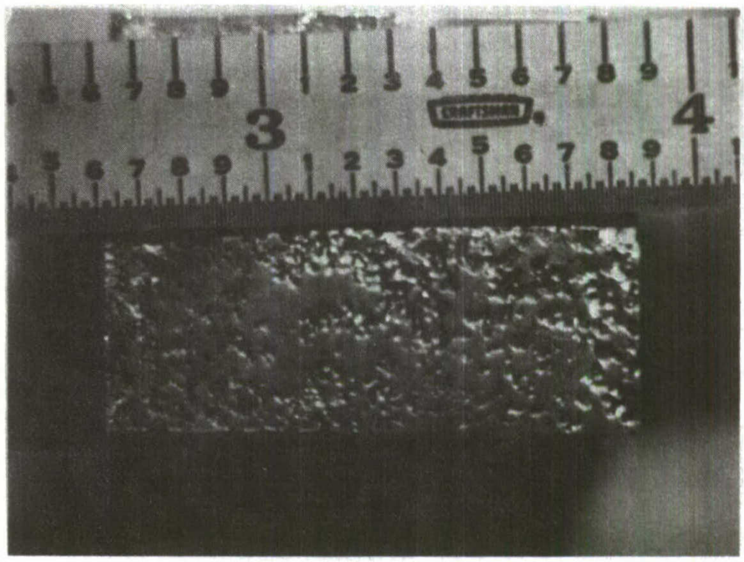

Figure 16. Aluminum 7475-T651 Stress Corrosion Cracking Sample (Top Free Surface).

TABLE 4

STRESS CORROSION CRACKING TEST RESULTS FOR ALUMINUM 7475-T651 AND T7351 IN A 3.5% NaCl SOLUTION

Specimen No.*	Heat Treat.	K_I (Initial)		Test Time		Exposure Prior to Test
		KSI $\sqrt{IN}$	MPA $\sqrt{m}$	Failure (hr)	No Failure (hr)	
6S3	T651	34.2	37.6	313.9		None
6S1		30.6	33.6		1036.4	None
7S1	T7351	30.5	33.5		1400	None
7S3		29.9	32.9		1082	None
6S10	T651	36.7	40.3	19.5		250 °F (121 °C) for 1000 hours
6S12		33.2	36.5		1134.9	250 °F (121 °C) for 1000 hours
7S7	T7351	26.9	29.6		827.7	250 °F (121 °C) for 1000 hours
7S9		27.8	30.5		1030.3	250 °F (121 °C) for 1000 hours

*Test at room temperature, all specimens are S-L orientation.

SECTION IV

SUMMARY

The following conclusions are based on test results of single plates of 7475 with the identical heat treatments. These findings could be altered by an in-depth program that included numerous lots of test material.

1. The test material is a high-strength 7000-series aluminum alloy.
2. The T651 heat treatment possesses higher strength than the T7351 processing.
3. The T7351 heat treatment appears to have higher toughness than the T651 processing.
4. A test material thickness of 1.5 inches is insufficient to obtain ASTM valid fracture toughness test results.
5. The 250°F (121°C) 1000-hour thermal cycle did not affect any of the mechanical properties test results to a great degree.
6. The test material demonstrated good fatigue life, with no clear cut distinction between heat treatments and orientation.
7. Under a cyclic loading condition the test material demonstrated crack growth rates directly comparable to other new 7000-series alloys; the crack growth rate was unaffected by the time-temperature exposure of 250°F (121°C) for 1000 hours.
8. Although the material is extensively pitted by the 3.5 percent sodium chloride test solution the material demonstrated good resistance to stress corrosion cracking.

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